

Displays and framebuffers

Reading

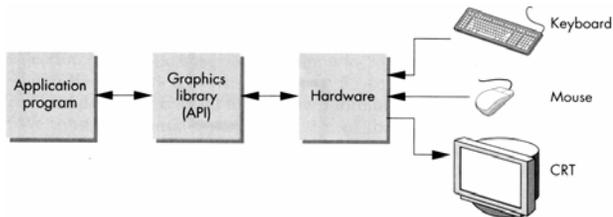
Required

- ♦ Angel, section 1.2, chapter 2
- ♦ Hearn & Baker, handout

Optional

- ♦ OpenGL Programming Guide (the “red book” – available online):
 - First four sections of chapter 2
 - First section of chapter 6
- ♦ Foley et al., sections 1.5, 4.2-4.5
- ♦ I.E. Sutherland. Sketchpad: a man-machine graphics communication system. *Proceedings of the Spring Joint Computer Conference*, p. 329-346, 1963.
- ♦ T.H. Myer & I.E. Sutherland. On the design of display processors. *Communications of the ACM* 11(6): 410-414, 1968.

Modern graphics systems



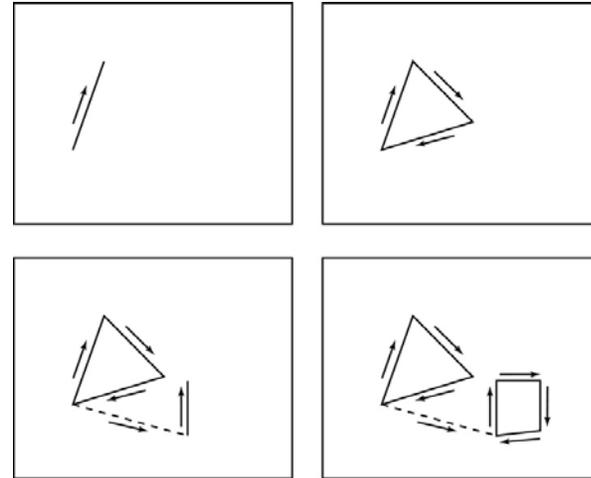
Current graphics systems consist of:

- An application, which talks to a...
- Graphics library (e.g., OpenGL or Direct3D), which talks to the...
- Graphics hardware

The graphics hardware can do a lot of fancy work these days. At a minimum, it contains a framebuffer to drive a display...

3

Calligraphic displays



Also called **vector displays**, **stroke displays**, or **random-scan displays**.

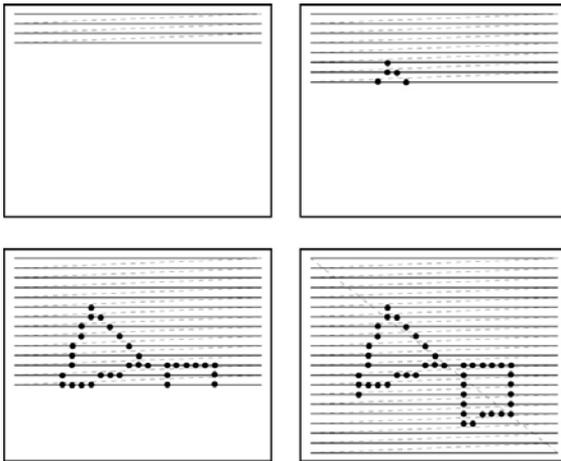
Used by:

- ♦ Asteroids video game
- ♦ Older oscilloscopes

4

Raster displays

ras.ter, from radere, "to scrape"

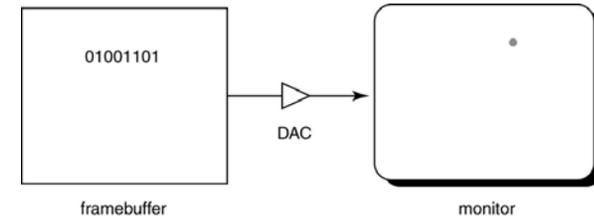


Electron beam traces over screen in **raster scan order**.

- ◆ Each left-to-right trace is called a **scan line**.
- ◆ Each spot on the screen is a **pixel**.
- ◆ When the beam is turned off to sweep back, that is a **retrace**, or a **blanking interval**.

5

Framebuffers



Intensity of the raster scan beam is modulated according to the contents of a **framebuffer**.

Each element of the framebuffer is associated with a single **pixel** on the screen.

Note: the brightness of a pixel is controlled by the voltage coming from the DAC, but the CRT has a non-linear response:

$$I \propto V^\gamma$$

Monitor gammas are typically around 1.7-2.5.

6

Aspect ratio

Typical workstation displays are designed to show 1280x1024 color pixels, giving a **resolution** of 75 dpi.

Frame aspect ratio = horizontal / vertical size

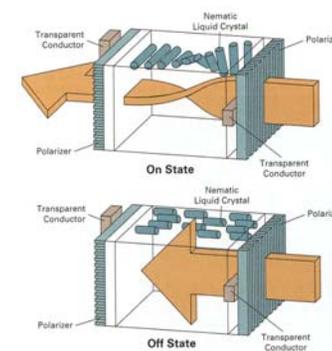
Typical CRT's	4 : 3
HDTV	16 : 9
35mm film	3 : 2
Panavision	2.35 : 1

Pixel aspect ratio = pixel width / pixel height

- ◆ nowadays, this is almost always 1.

7

Liquid Crystal Displays



Laptops typically use **liquid crystal displays (LCD's)**.

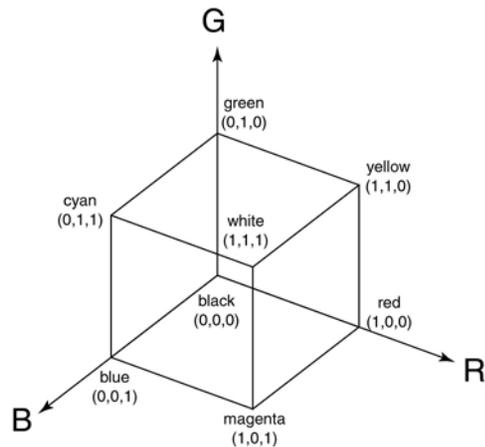
- ◆ Light enters a **vertical polarizer**
- ◆ **Nematic crystal** twists light based on applied voltage (more voltage, less twisting)
- ◆ Light passes through **horizontal polarizer**

Active matrix displays have a transistor at each cell. They use a fast switching crystal and transistors that hold charge and prevent overflow.

Color filters are used to get color display.

8

Additive color mixing



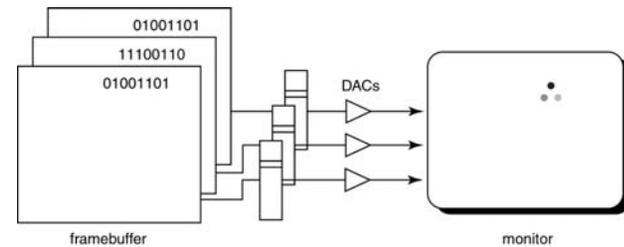
All colors on a monitor or LCD are produced using combinations of red, green, and blue.

A display that allows 256 voltage settings for each of R, G, and B is known as a **full-color system**.

The description of each color in framebuffer memory is known as a **channel**.

9

RGB framebuffer



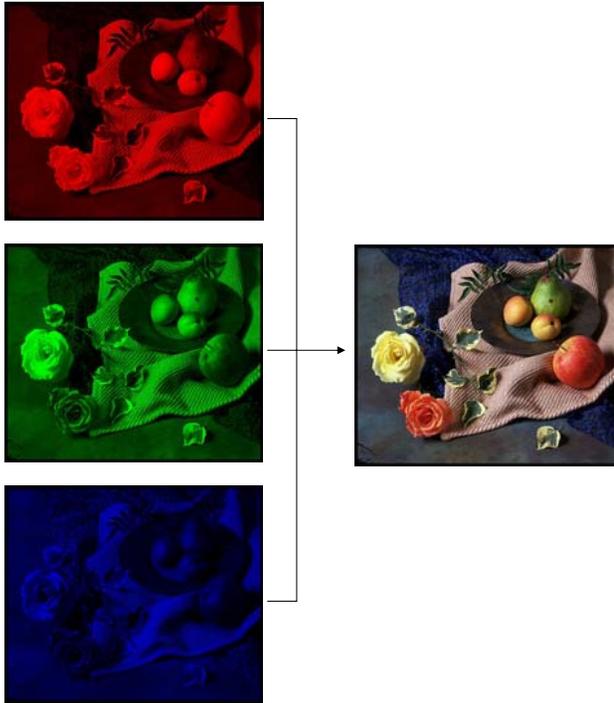
Originally, color was formed by mapping each framebuffer byte to three bytes (RGB) through a lookup table.

The term **true-color** is sometimes used to refer to systems which the framebuffer directly stores the values of each channel.

As memory prices have fallen, true-color has become fairly standard.

10

Anatomy of an RGB image

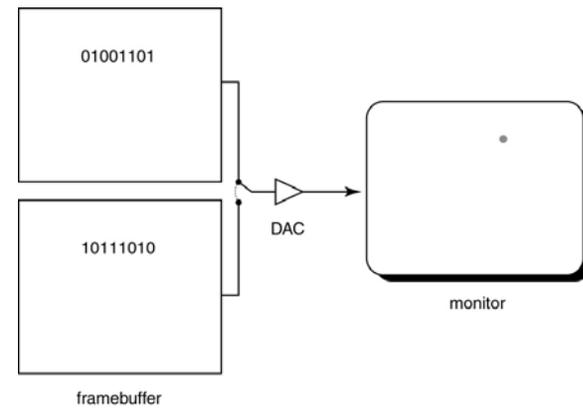


11

Double-buffering

Q: What happens when you write to the framebuffer while it is being displayed on the monitor?

Double-buffering provides a solution.



12

OpenGL

The API we'll be using for drawing to the framebuffer is OpenGL.

For 2D graphics, OpenGL lets you specify colors of primitives and then draw them to the screen.

Typical primitives include:

- ◆ Points
- ◆ Lines
- ◆ Unfilled polygons
- ◆ Filled polygons

You just name a color, declare the primitive type, and specify the vertices, and OpenGL does the rest.

OpenGL also supports “alpha” blending. A typical operation is a linear mixture that blends a new color into the framebuffer:

$$F_{new} = \alpha C + (1 - \alpha) F_{old}$$

13

Summary

Here's what you should take home from this lecture:

- ◆ All of the **boldfaced terms**.
- ◆ Raster vs. calligraphic displays.
- ◆ The principles of operation for an LCD display.
- ◆ The correspondence between elements of framebuffer memory and pixels on-screen.
- ◆ How double-buffering works.

14